

SIMULTANEOUS MULTISPECTRAL OPTICAL MEASUREMENT OF PHYTOPLANKTON AND ACOUSTIC MEASUREMENT OF ZOOPLANKTON

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LONG TERM GOALS

The long-range scientific objectives of our program are to understand and characterize the underlying processes, both physical and behavioral, which govern the spatial distribution of phytoplankton and the foraging behavior of the predatory zooplankton. This will include mathematical models of the physics and biology.

OBJECTIVES

Our objectives are to quantify the microscale and fine-scale vertical and horizontal patchiness of two taxa of phytoplankton and zooplankton in situ. This includes knowledge of the 3-d statistics of the patchiness of phytoplankton and zooplankton on scales <1 km, to a resolution of centimeters, and their relation to the ambient physical environment. The multispectral optical system will allow us to quantify the correlation of zooplankton with phytoplankton patches of differing species composition and the dynamic response of zooplankton to phytoplankton patchiness under a variety of conditions.

APPROACH

We have developed a novel optical instrument (Low light-level Underwater Multispectral Imaging System, LUMIS) for measuring phytoplankton fluorescence in two wavebands, coincidently with the measurement of optical scattering and Raman inelastic scatter. The wavelengths resolved are 577 nm (phycoerythrin), 680 nm (chlorophyll a), 651 nm (Raman) and 532 nm for scattering (the stimulating laser wavelength). This instrument was mounted on the same platform as the FishTV, an acoustic instrument allowing 3-d imaging of acoustic targets: 6 mm at 445 kHz and 1 mm at 1.6 MHz. The two instruments were deployed simultaneously in Saanich Inlet, British Columbia, in August of 1997. The measurements with these two new instruments were supported by simultaneous collection of water samples for measurement of various phytoplanktonic taxa, and by vertical profiles obtained with a CTD/fluorometer/transmissometer package.

WORK COMPLETED

The LUMIS system has been constructed and tested in a laboratory tank and in the field in its first in situ deployment. The laboratory calibration experiment used bottled samples of pure cultures of *Synechococcus* (phycoerythrin-containing phytoplankton) and *Thalassiosira* (chlorophyll a-containing phytoplankton). The system consists of a fiber-optic network which relays the four images from the lenses to the digital camera. Each lens has appropriate filters to image each of the four chosen wavebands. A doubled Nd-YAG laser is used to stimulate fluorescence at 532 nm. The system has been deployed in the Red Sea in May, 1997, and in Saanich Inlet in August, 1997, allowing comparison of an oligotrophic and mesotrophic environment.

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Models of copepod foraging behavior in patchy environments have been developed, based on laboratory and field measurements of zooplankton distributions in relation to phytoplankton patchiness. These 1-d and 2-d spatially resolved, individual-based models are a testbed for zooplankton feeding and swimming dynamics, and have been parameterized with data from laboratory experiments.

RESULTS

Techniques for processing the 2-d images of fluorescence patchiness have been developed, including algorithms for computing the 1-, 2- and 3-d Fourier spectra of fluorescence variance, assuming spatial isotropy (Fig. 1). These techniques allow comparison of the measured spatial spectra to predicted spectra of tracers in a turbulent fluid. From data gathered during a cruise off San Diego in July of 1995, we have found relatively invariant spatial spectra throughout the water column, suggesting that physical processes were structuring the microscale fluorescence field.

The deployment of the camera system was hampered by ship heave, leading to smearing of images. Fourier techniques were developed to identify unsmear images, which were used in subsequent analyses. Our contention that these images were uncontaminated by the instrument or ship heave was supported by data from the FishTV system showing that the current was flowing toward the instrument at up to 50 cm/s, suggesting that turbulence from the instrument package was not affecting the imaged region (1 m in front of the camera system).

An example of an image obtained during the Saanich Inlet deployment is shown in Fig. 2. This image has been corrected for thermal variations in the camera; the camera is so sensitive that small variations in temperature appear as gradients in the images. The image has not been corrected for variations in the laser intensity, thus the main signal is the brightness of the laser beam and stimulated fluorescence. Once our algorithms for eliminating the effects of laser intensity have been applied, the microscale patchiness of fluorescence and scattering will be more apparent. It is obvious from the image that the main signal is in the scattering and chlorophyll a channels. This is consistent with the bottle samples, which showed relatively high concentrations of chlorophyll a, but low concentrations of phycoerythrin-containing phytoplankton.

Figure 1: Three-dimensional spatial spectra from 240 good images gathered during July 1995 off San Diego. The spectra indicate random patterns at scales larger than about 3 cm, and less variance than random at smaller scales.

Figure 2. Four images taken simultaneously with the LUMIS camera system: upper left=chlorophyll a, upper right=phycoerythrin, lower left=Raman, lower right=laser scattering. These images have been corrected for variations in the dark current, but not for variations in the laser intensity

IMPACT

This new instrument platform has the possibility of giving us the first in situ view of the microscale patchiness of several taxa of phytoplankton, coincident with the distributions of zooplankton. These data, combined with the models developed during this research will allow a better understanding and ability to predict the distributions and dynamics of zooplankton and other small acoustic targets.

TRANSITIONS

RELATIONSHIPS TO OTHER PROJECTS

This work has benefitted other work in Jaffe's laboratory with optical calibrations of the FishTV, sponsored by NSF. In addition, collaborations with scientists in Israel have facilitated the deployment of these instruments in diverse environments.